DISPLAY DEVICE

[0001] This application is a continuation of International Application No. PCT/US2017/052573, filed Sep. 20, 2017, which claims benefit of priority to U.S. application Ser. No. 15/709,398, filed Sep. 19, 2017, which is abandon, which claims benefit of priority to U.S. Provisional Application No. 62/397,312, filed Sep. 20, 2016. The above applications are incorporated herein by reference. To the extent that any material in the incorporated application conflicts with material expressly set forth herein, the material expressly set forth herein controls.

BACKGROUND

[0002] Virtual reality (VR) allows users to experience and/or interact with an immersive artificial environment, such that the user feels as if they were physically in that environment. For example, virtual reality systems may display stereoscopic scenes to users in order to create an illusion of depth, and a computer may adjust the scene content in real-time to provide the illusion of the user moving within the scene. When the user views images through a virtual reality system, the user may thus feel as if they are moving within the scenes from a first-person point of view. Similarly, augmented reality (AR) and mixed reality (MR) combine computer generated information with views of the real world to augment, or add content to, a user's view of their environment. The simulated environments of VR and/or the enhanced content of AR/MR may thus be utilized to provide an interactive user experience for multiple applications, such as interacting with virtual training environments, gaming, remotely controlling drones or other mechanical systems, viewing digital media content, interacting with the internet, or the like.

[0003] However, conventional VR, AR, and MR systems may suffer from accommodation-convergence mismatch problems that cause eyestrain, headaches, and/or nausea.

[0004] Accommodation-convergence mismatch arises when a VR or AR system effectively confuses the brain of a user by generating scene content that does not match the depth expected by the brain based on the stereo convergence of the two eyes of the user. For example, in a stereoscopic system the images displayed to the user may trick the eye(s) into focusing at a far distance while an image is physically being displayed at a closer distance. In other words, the eyes may be attempting to focus on a different image plane or focal depth compared to the focal depth of the projected image, thereby leading to eyestrain and/or increasing mental stress. Accommodation-convergence mismatch problems are undesirable and may distract users or otherwise detract from their enjoyment and endurance levels (i.e. tolerance) of virtual reality or augmented reality environments.

SUMMARY

[0005] Various embodiments of an augmented reality (AR), and/or mixed reality (MR) direct retinal projector system that may include an AR headset (e.g., a helmet, goggles, or glasses) that uses a reflective holographic combiner to direct light from a light engine into the user's eye, while also transmitting light from the user's environment to thus provide an augmented view of reality. The holographic combiner may be recorded with a series of point to point holograms; one projection point interacts with multiple holograms to project light onto multiple eye box points. The holograms may be arranged so that neighboring eye box points are illuminated from different projection points. The holographic combiner and light engine may be arranged to separately project light fields with different fields of view and resolution that optimize performance, system complexity and efficiency, so as to match the visual acuity of the eye. The light engine may implement foveal projectors that generally project wider diameter beams over a smaller central field of view, and peripheral projectors that generally project smaller diameter beams over a wider field of view.

[0006] The light engine may include multiple independent light sources (e.g., laser diodes, LEDs, etc.) that can independently project from the different projection points, with a proportion being foveal projectors and a proportion being peripheral projectors. In some embodiments, the light engine may include two or more two-axis scanning mirrors to scan the light sources; the light sources are appropriately modulated to generate the desired image. The light engine may include a series of optical waveguides with holographic or diffractive gratings that move the light from the light sources to generate beams at the appropriate angles and positions to illuminate the scanning mirrors; the light is then directed into additional optical waveguides with holographic film layers recorded with diffraction gratings to expand the projector aperture and to maneuver the light to the projection positions required by the holographic combiner.

[0007] In some embodiments, the light engine may include at least one focusing element (e.g., optical lens, holographic lens, etc.) for each projector to focus emitted light beams such that, once reflected off the holographic combiner, the light is substantially collimated when it enters the subject's eye. The required focal surface may be complicated by the astigmatism of the holographic combiner, but is a curved surface in front of the combiner. The ideal focal surface is different for different eye box positions, and errors may lead to less collimated output. However, in some embodiments, this can be compensated by reducing the beam diameter for different angles where the errors between the ideal focal surface and the actual best fit focal surface are greatest, which alleviates the problem by increasing the F-number and hence the depth of focus of the beam.

[0008] In some embodiments, active beam focusing elements may be provided for each projection point. This may reduce or eliminate the need to change beam diameter with angle. This may also enable beams that diverge into the eye to, rather than being collimated, match the beam divergence of the supposed depth of the virtual object(s) being projected by the light engine.

[0009] The AR system may not require extra moving parts or mechanically active elements to compensate for the eye changing position in the eye box or for the changing optical power from the holographic combiner during the scan, which simplifies the system architecture when compared to other direct retinal projector systems. Further, the holographic combiner may be implemented by a relatively flat lens when compared to curved reflective mirrors used in other direct retinal projector systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is an example of different types of eye focus.

[0011] FIG. 2 illustrates one embodiment of a conventional near-eye virtual reality system.

[0012] FIG. 3 illustrates an example of parallel light beams entering an eye.